Copper Coated PEEK Based RF Cavity Power and Q Factor Testing

Benjamin Sims (AOT-AE)
John W. Lewellen (LAMP)

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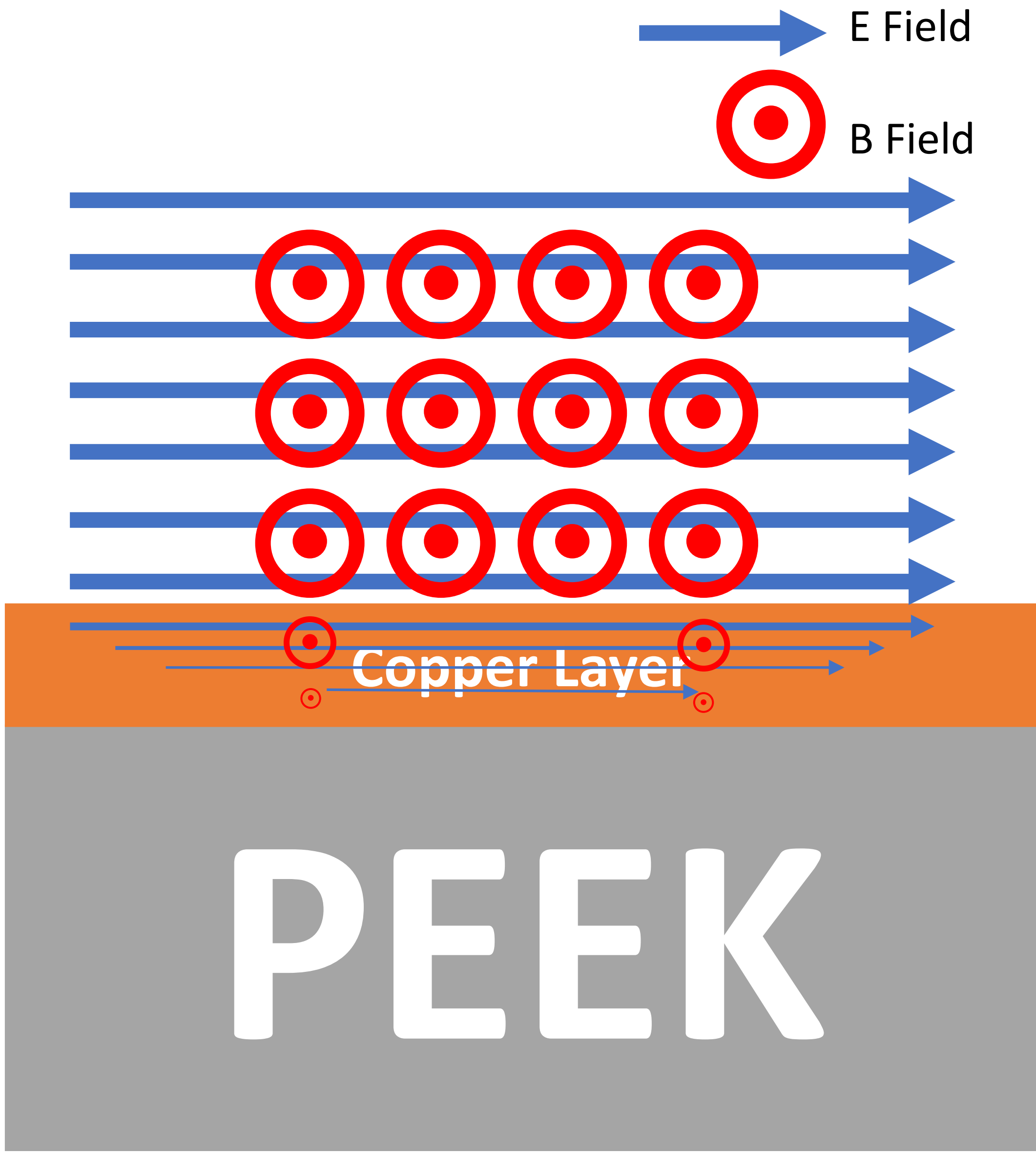
Polyether Ether Ketone (PEEK) Based Cavities

- Copper coated polymer structures have been implemented in many radiofrequency applications

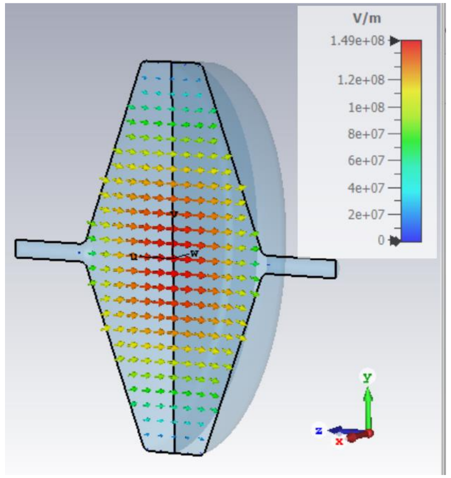
- Examples include
  - Lightweight and unique antennas
  - Waveguides
  - Prototype and Cold test RF structures



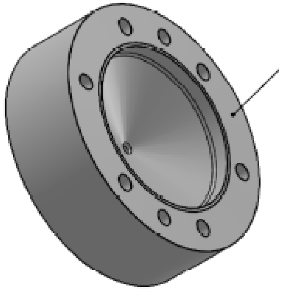
Simple PEEK Cavity Diagram

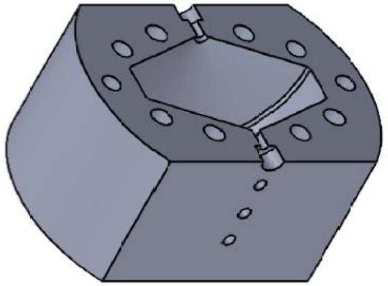
Designing and Building Cavities

Simulation

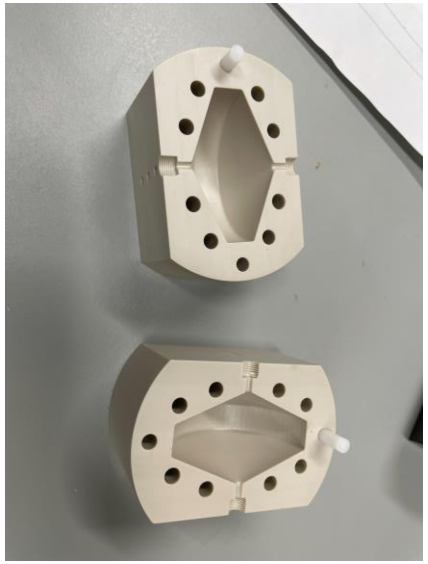


Fabrication designs

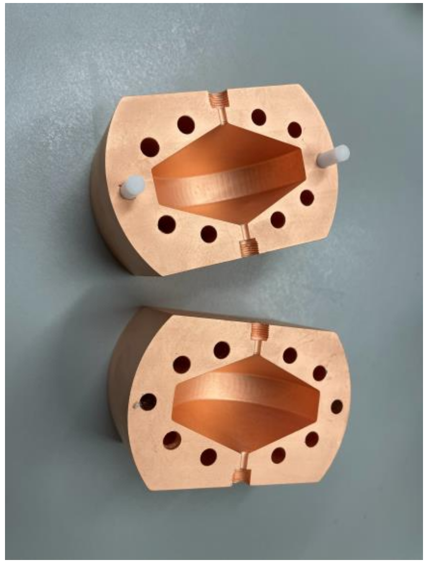




Fabrication

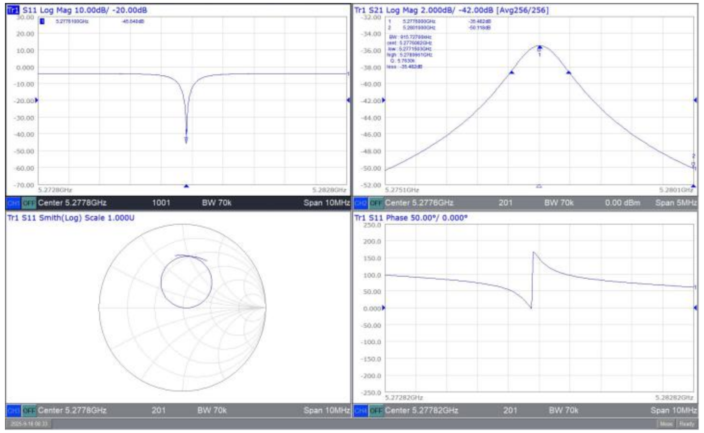


Plating



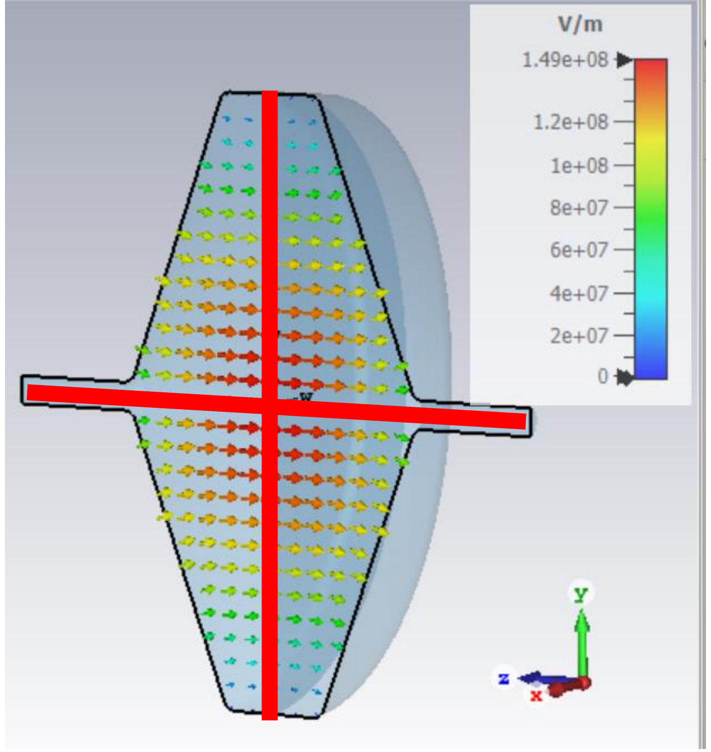
10 micron thickness

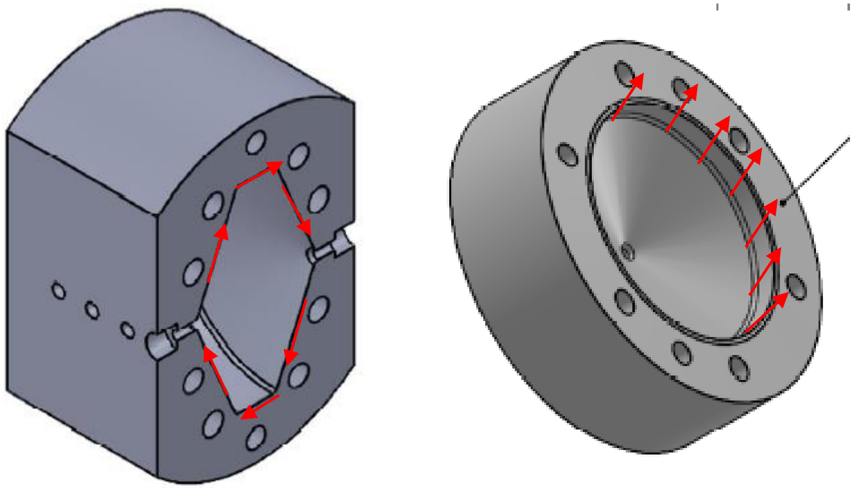
Characterization



Simulation and Fabrication designs

- Designed in CST
- Cavity Cuts
  - Equatorial Cut
    - Typical design approach
    - RF currents cross cavity cut
  - Longitudinal Cut
    - Emerging approach for high-gradient cavities
    - RF currents do not cross the cavity cut
      - Currents move parallel to cut line

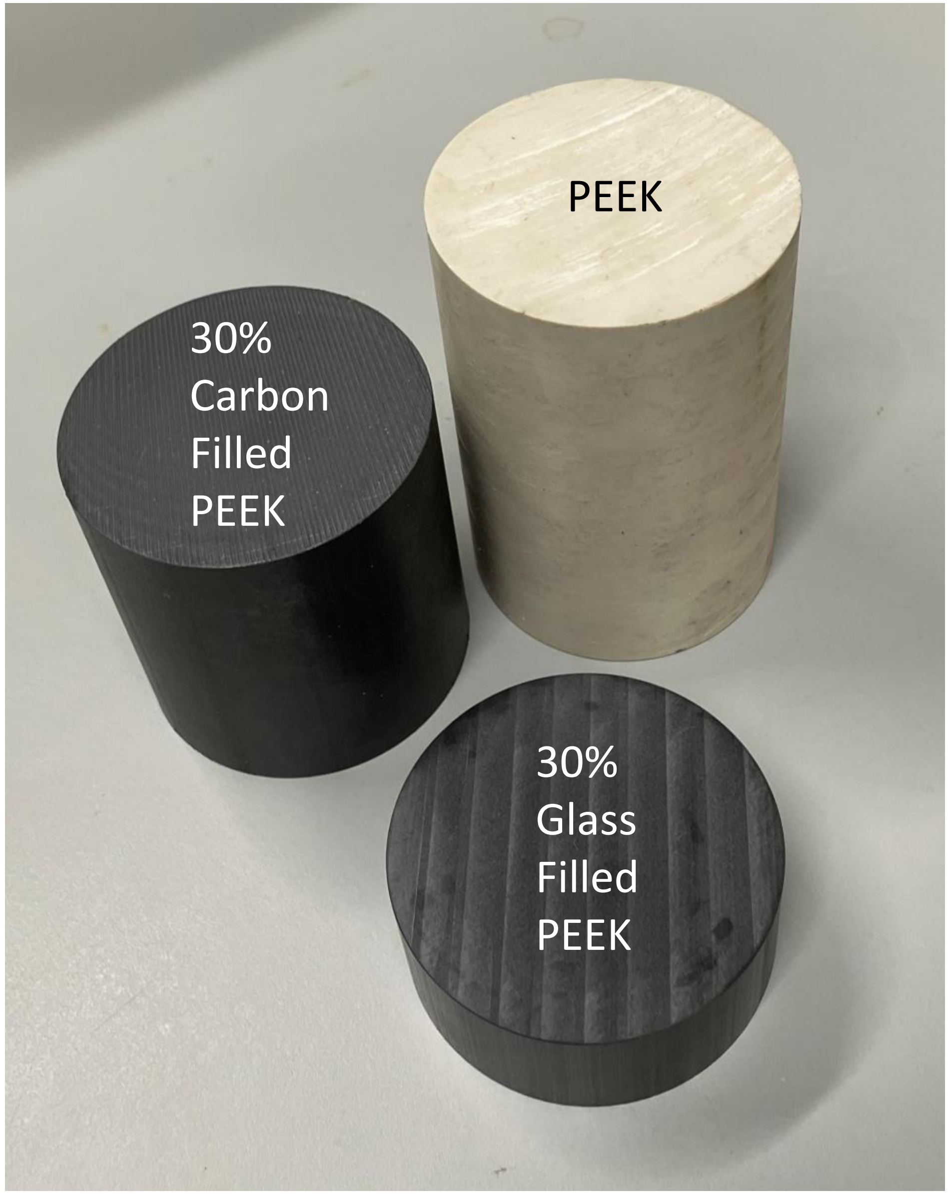




Testing a verity of materials

- Commercial off the Shelf (COTS) materials

- 3 Different Types of PEEK were tested
  - Basic PEEK plastic
  - 30% glass-filled PEEK
  - 30% carbon fiber-filled PEEK



COTS PEEK

Cavity Characterization

- Measurements Approach:
  - Port 1 critical coupled
  - Port 2 strongly under coupled
  - Est. accuracy ± 10%
  - $Q_0 = (1 + \beta_1 + \beta_2)Q_{ext}$
  - $\beta_1 \approx 1\ (Critical\ Coupling), \beta_2 \sim 0 (Under\ Coupled)$
  - $Q_0 = (2)Q_{ext}$

- CST Cavity RF design
  - Design Resonant frequency - 5.33 GHz
  - Design Q_0 ~10,800
  - $\beta_2 \sim 0$ assumption can lead to over estimation of Q_0

Measured Frequency

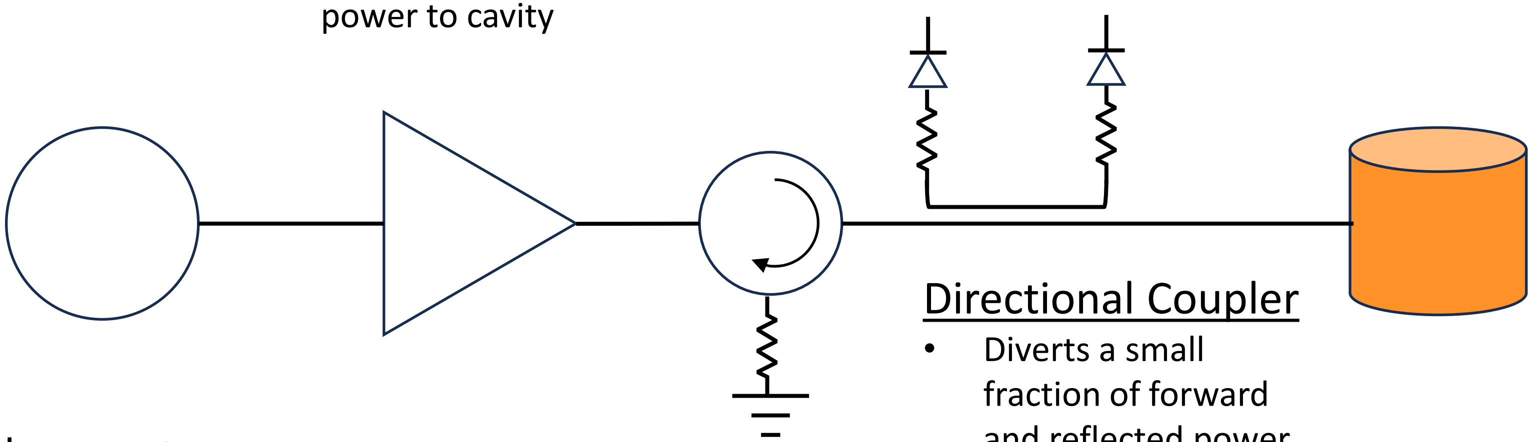
	PEEK [GHz]	30% GF PEEK [GHz]	30% CF PEEK [GHz]
Equatorial	5.29	5.29	5.29
Longitudinal	5.27	5.29	5.28

Measured Q_0

	PEEK	30% GF PEEK	30% CF PEEK
Equatorial	9,400	9,840	13,500
Longitudinal	11,200	9,440	10,070

Quality Factor and Resonant Frequency Data Tables

RF Power Testing



<u>Power Amplifier</u>
- Provides high average power to cavity

<u>Envelope Detector Diodes</u>
- Measures RF power sent to, and reflected from, cavity.

<u>Directional Coupler</u>
- Diverts a small fraction of forward and reflected power

<u>Signal generator</u>
- Gated to provide pulsed power to cavity
- Adjusted to match cavity frequency as the cavity expanded under RF heating

<u>Circulator</u>
- Directs reflected power from cavity into a load
- Protects amplifier from sudden cavity failure

RF Power diagram

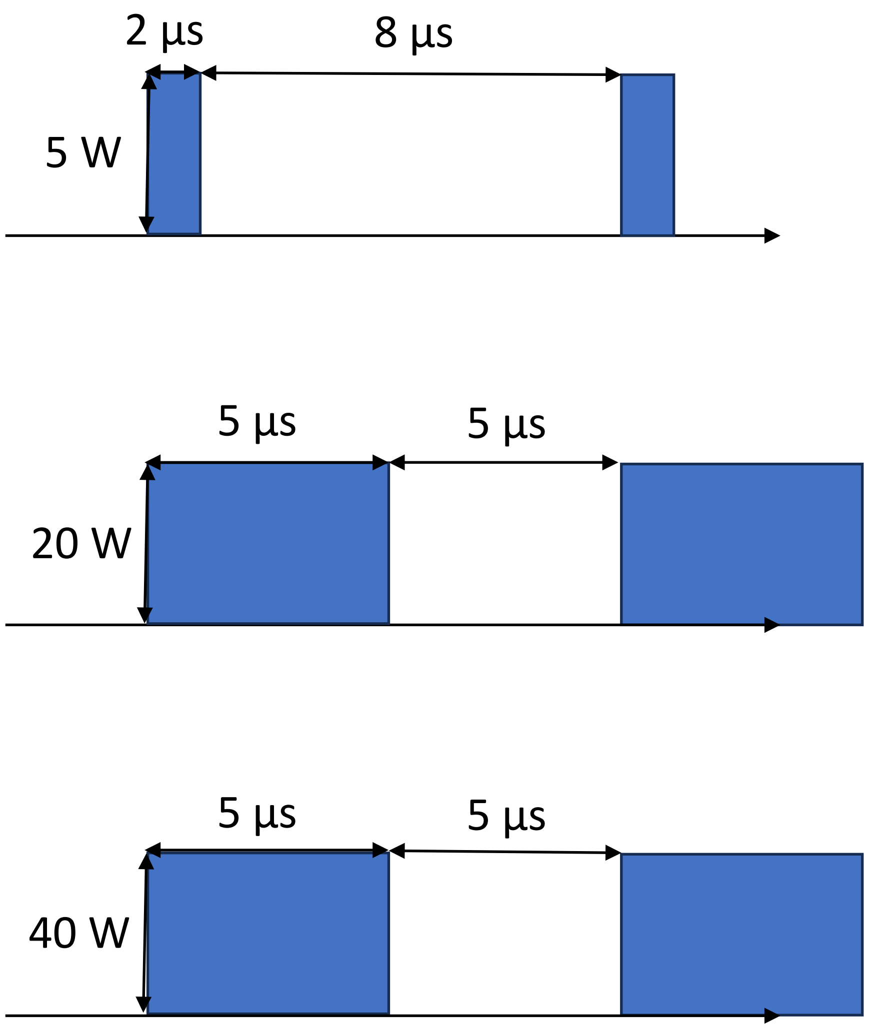
From Polymer Accelerator Structures, J. Lewellen

Power Testing Levels

- 1 W Average, 5 W Peak, 20% Duty Factor, 10-minute duration

- 10 W average power, 20 W peak, 50% Duty Factor, 10-minute duration

- 20 W Average Power, 40 W Peak, 50% Duty Factor, 30-minute duration



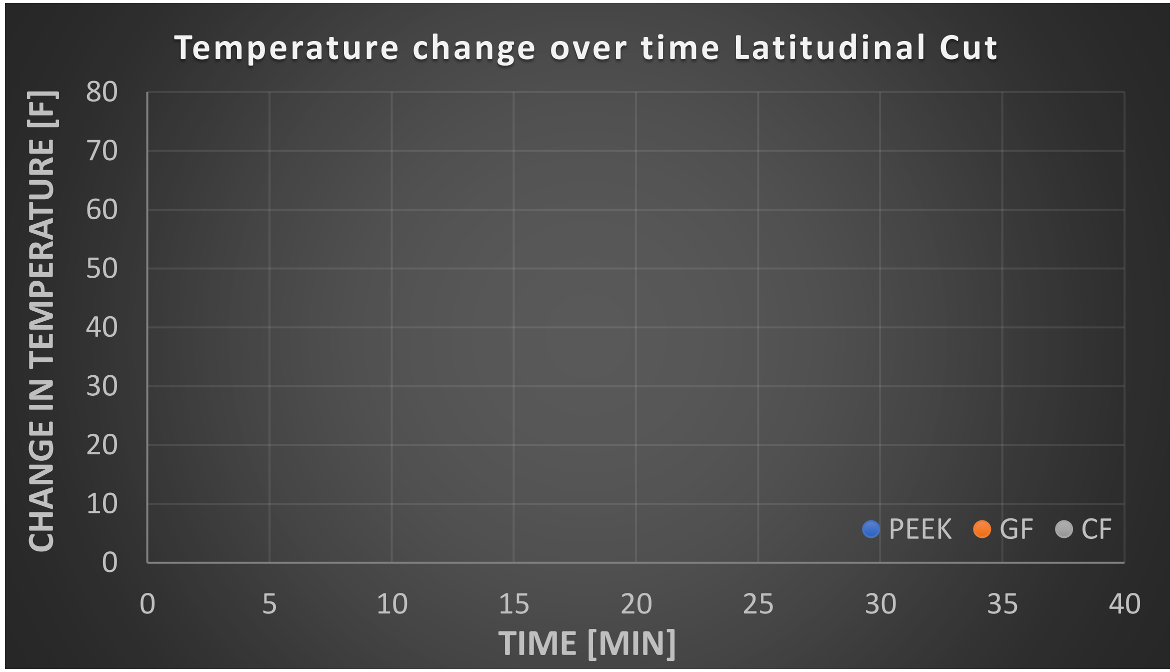
Power Delivered to Cavities

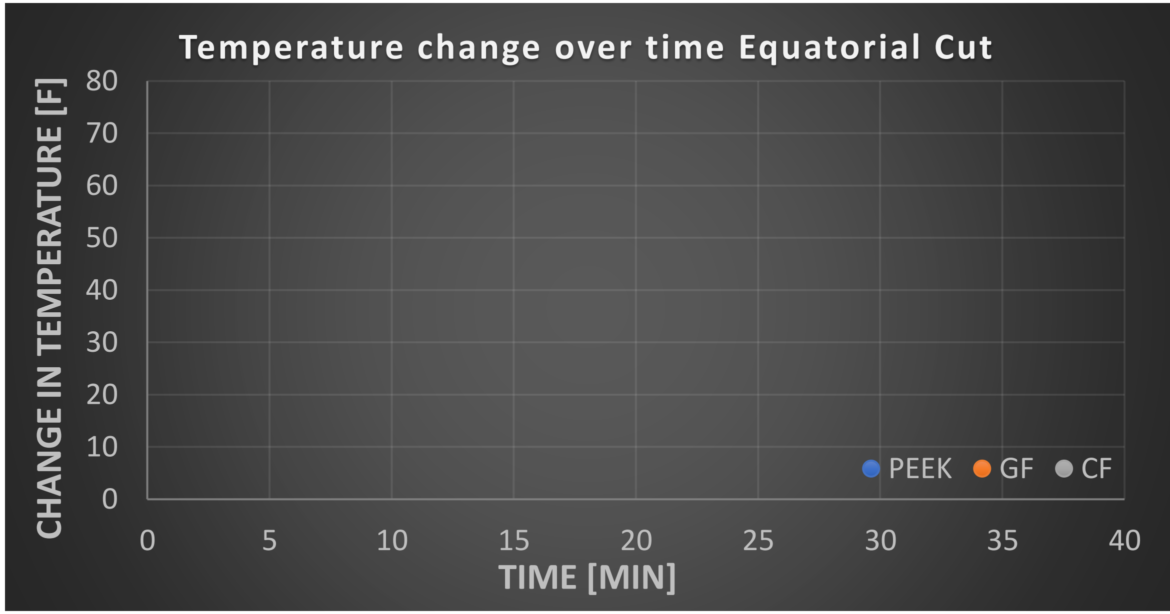
Cavity temperature rise

- Biggest Temperature change of ~70°F
- 20W Avg, 40W Peak

- RF Power turned off at 30 min
- Cooled down for 5 min

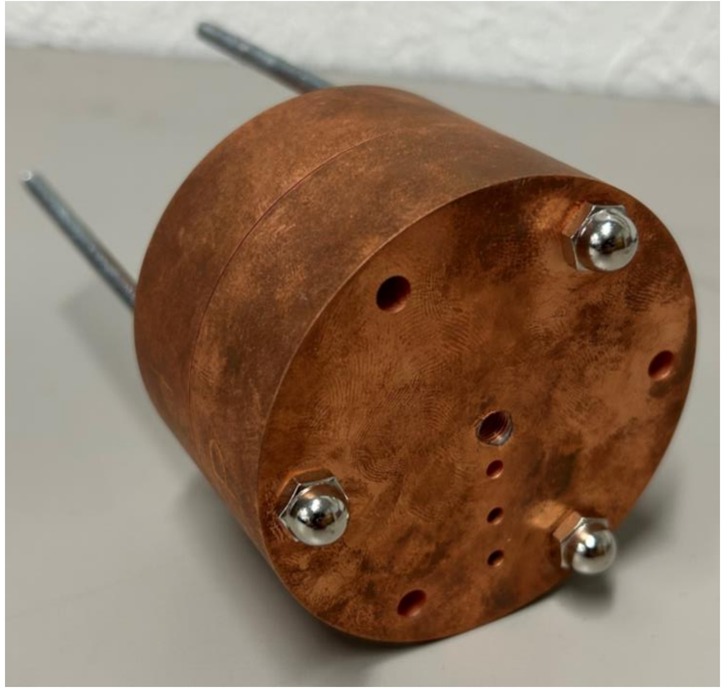
- Input frequency was monitored and modified to deliver critical coupling while cavity was in use





Material Comparison

- No large discernable changes between materials
- CF cavities cooled slightly faster
- PEEK Cavities cooled the slowest
- CF Cavities had the least resonant frequency change while heating
- PEEK Cavities had the largest resonant frequency change while heating
- Inner coating unblemished on all cavities

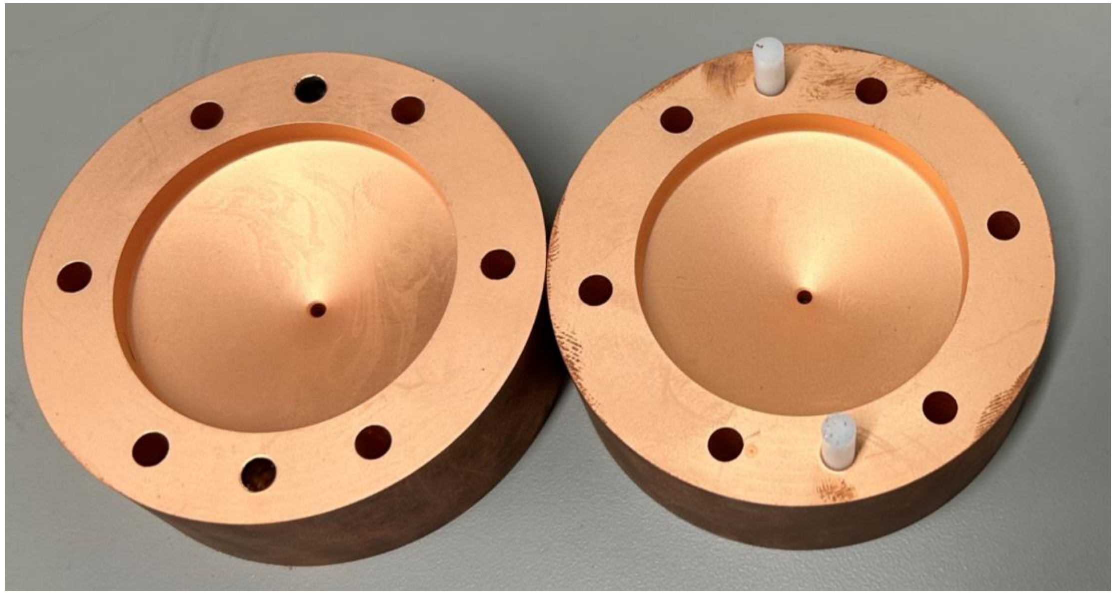


No, we did not use gloves

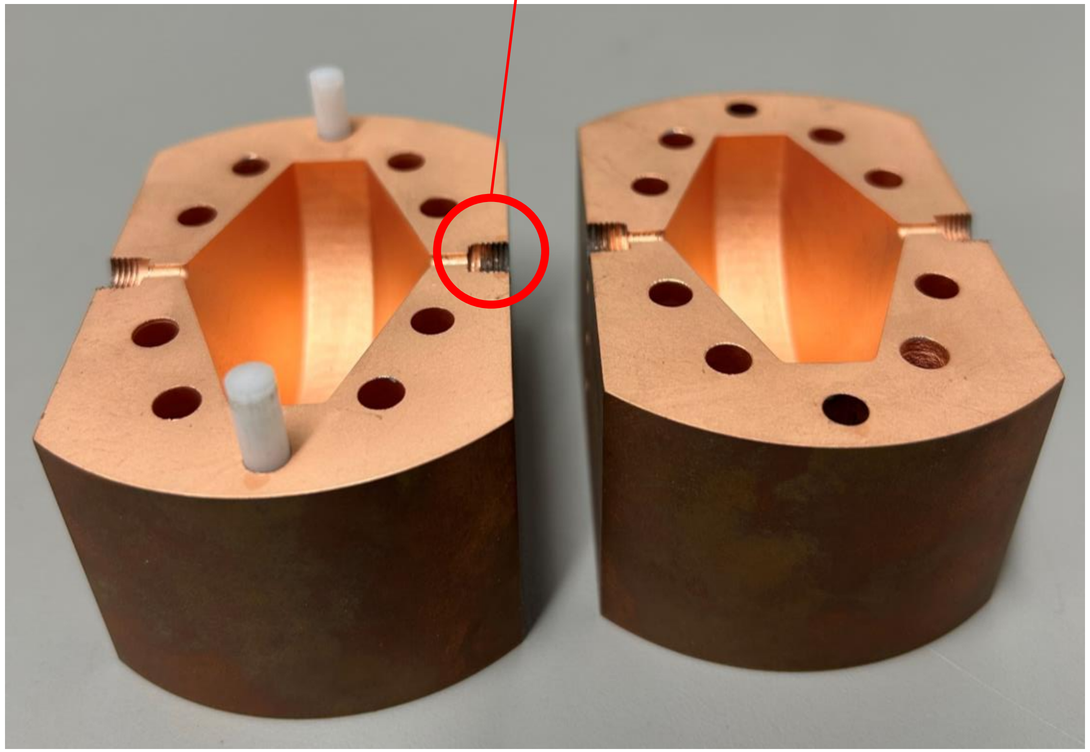
Post Testing Cavity

Undamaged inner surface

- PEEK Cavities after all testing



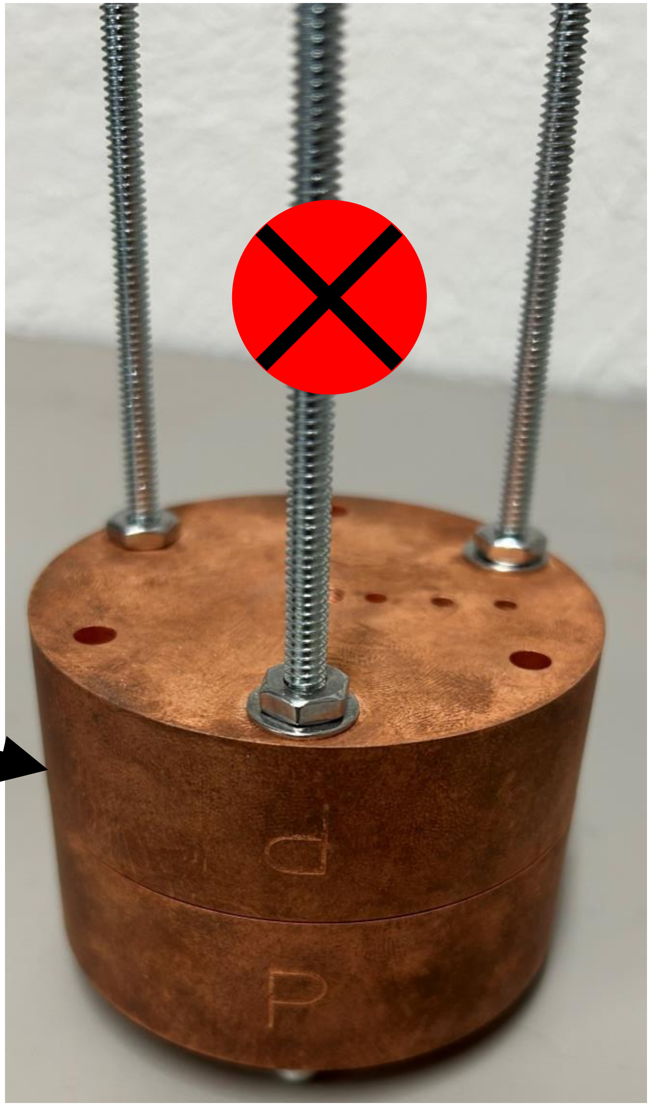
Repeated use led to coating removal from some threads

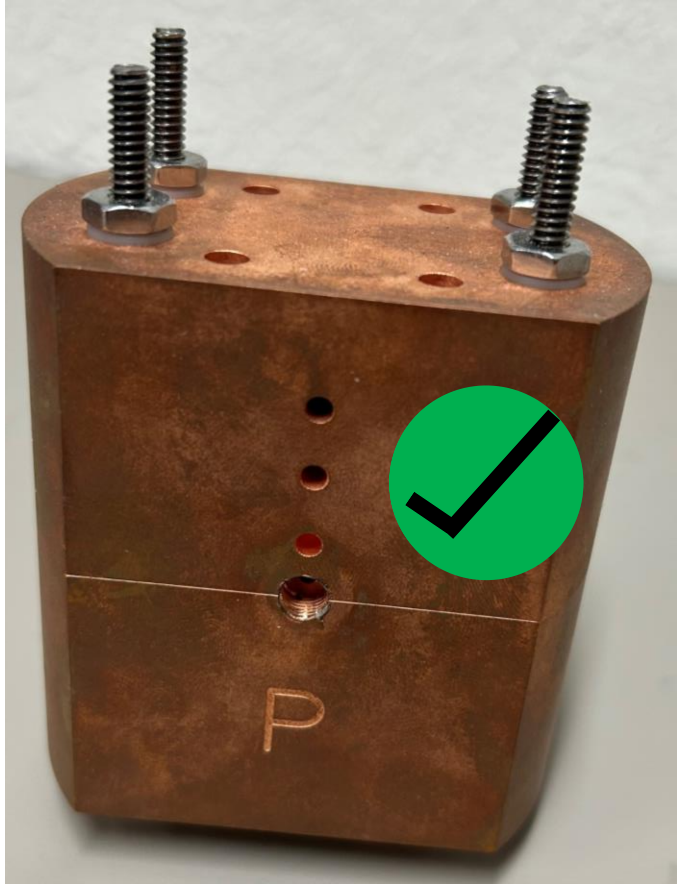


PEEK Cavities Internal Post Testing

Cavity compression

- Repeated heating and cooling caused bolts to loosen
- Resulted in a Q Factor drop following tests only for elliptical cut cavities
- Tightening bolts restored Q factor to pre-power delivery levels





Assembled PEEK Cavity

Conclusion

Parameter	PEEK CAVITY / COPPER CAVITY
Fabrication Time	1/4
Cost	1/10
Weight	1/10
Yield Strength	2.5
Q Factor	Equal

- No permanent deterioration in performance in any cavity following power testing
  - Equatorial cut showed the largest degradation in performance due to expansion at the joint causing loosening over time
  - Longitudinal cut performed better overall

Questions?

Thank you for your time.